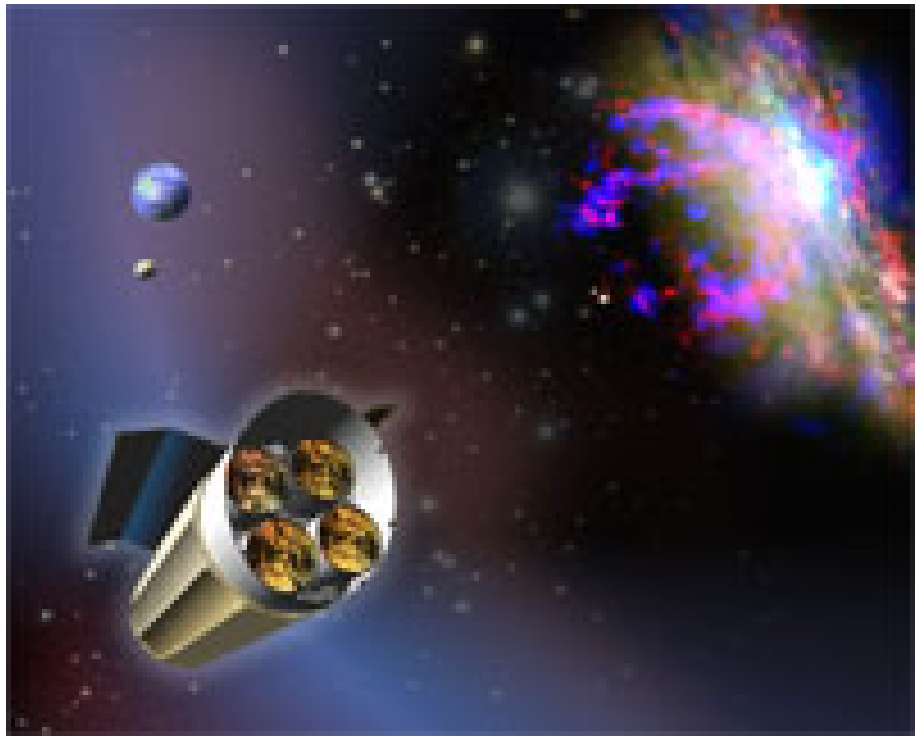
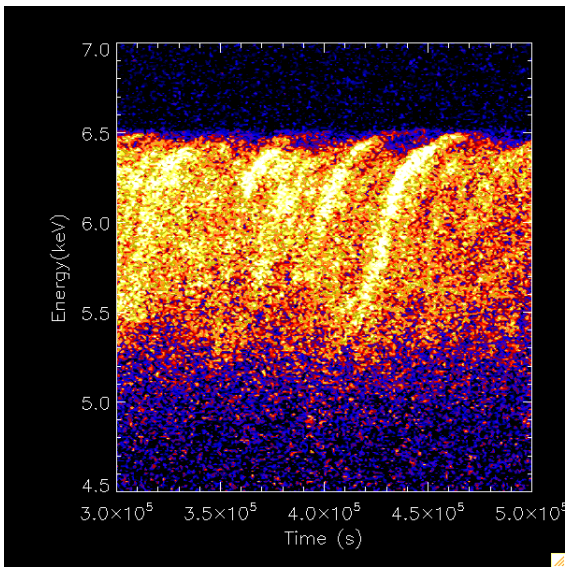
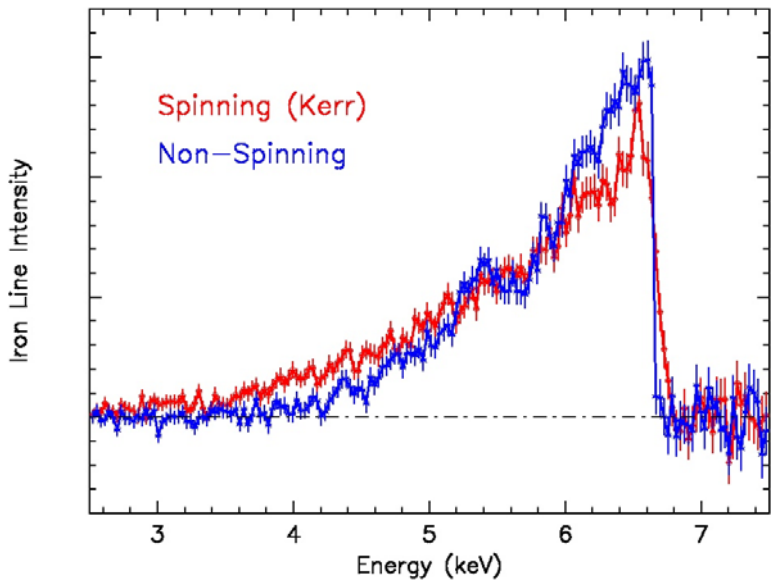
Hard X-ray Considerations for Iron K Line Studies with Con-X

James Reeves (JHU/GSFC) and Kim Weaver (GSFC)







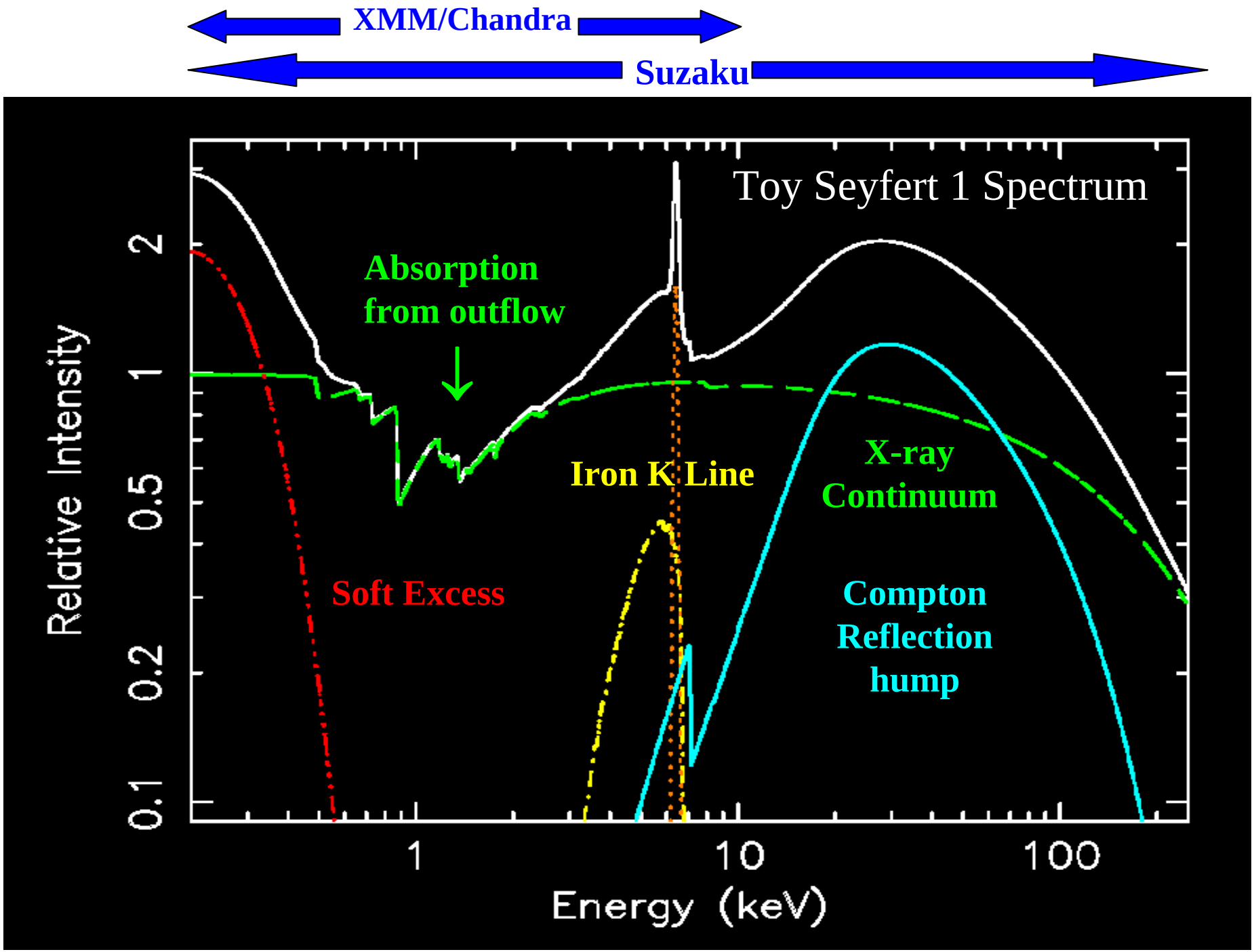
Background

- Early ASCA results on AGN appeared to show that relativistic iron K lines were commonplace.

- Subsequent observations with XMM-Newton/Chandra revealed that the de-convolution of a narrow 6.4 keV line (from a distant re-processor) was under-estimated.

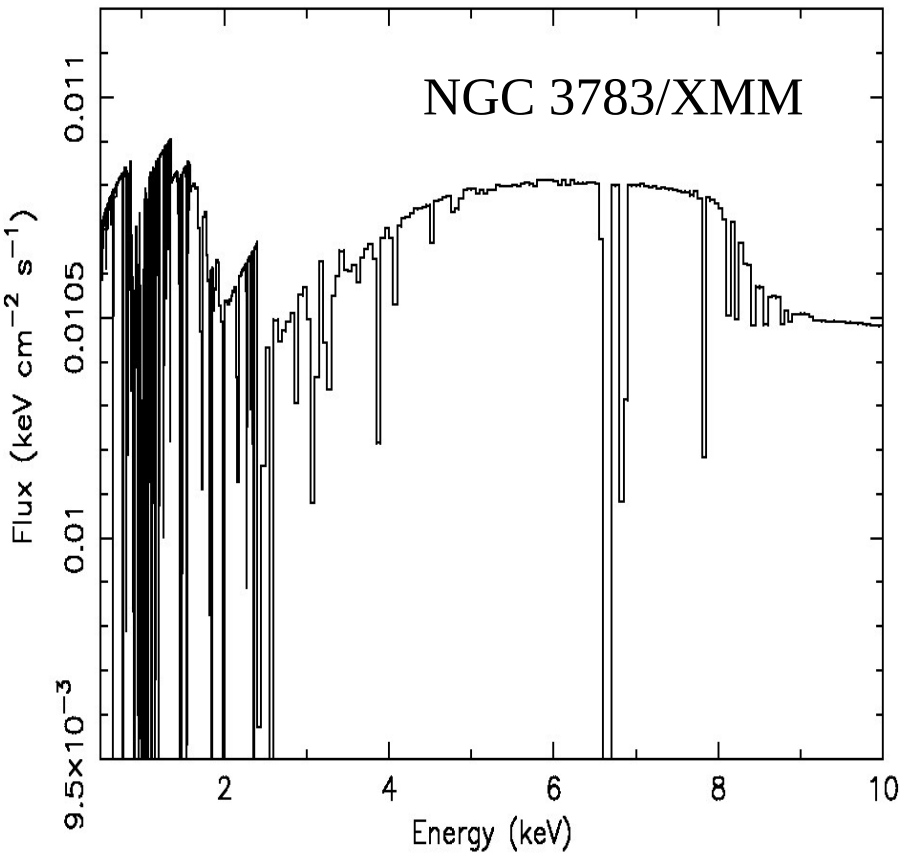
- In addition the opacity from a complex “warm” absorber has been under-estimated in the iron K band. The combination of absorption plus undetermined Compton reflection on data of limited bandpass (below 10 keV), plus limited exposures in early XMM observations, led to degeneracy in fitting the broad iron line.

- Broad-band Suzaku observations are now able to break the degeneracy between complex absorption, reflection and the relativistic line, revealing robust examples of relativistic lines (e.g. MCG -6-30-15, MCG -5-23-16, 3C 120, NGC 2992, NGC 3516 etc).

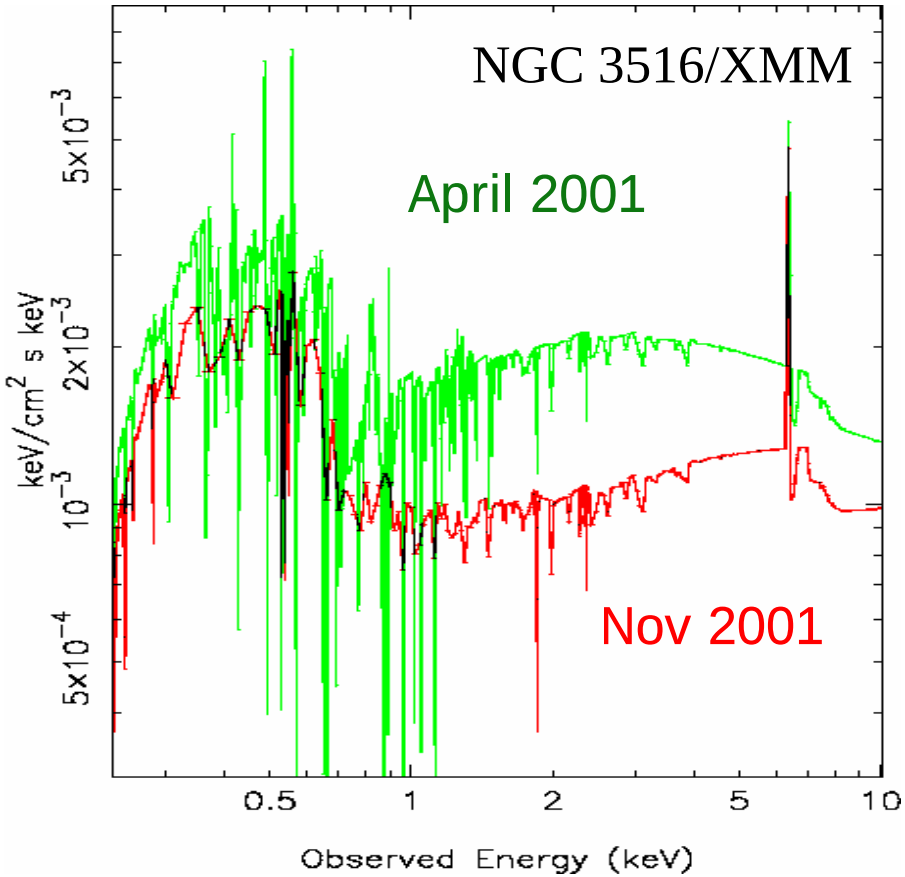

XMM/Chandra
Suzaku
Toy Seyfert 1 Spectrum
Absorption
from outflow
Iron K Line
X-ray
Continuum
Soft Excess
Compton
Reflection
hump
Relative Intensity
0.1
0.2
0.5
1
2
1
10
100
Energy (keV)

In studying broad Fe K line, the effects of X-ray absorption need to be accounted for

Reeves et al. 2004

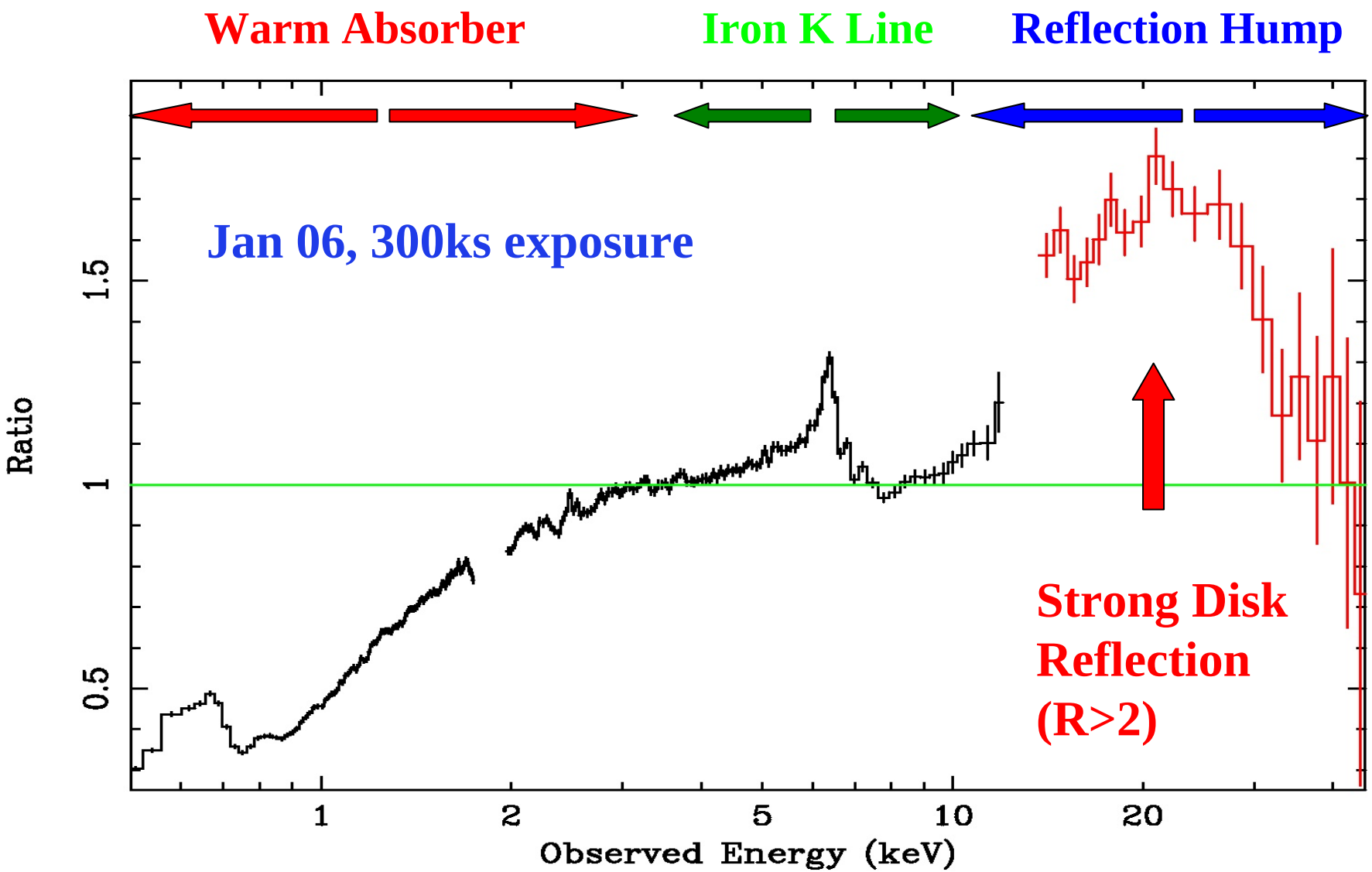


Turner et al. 2005

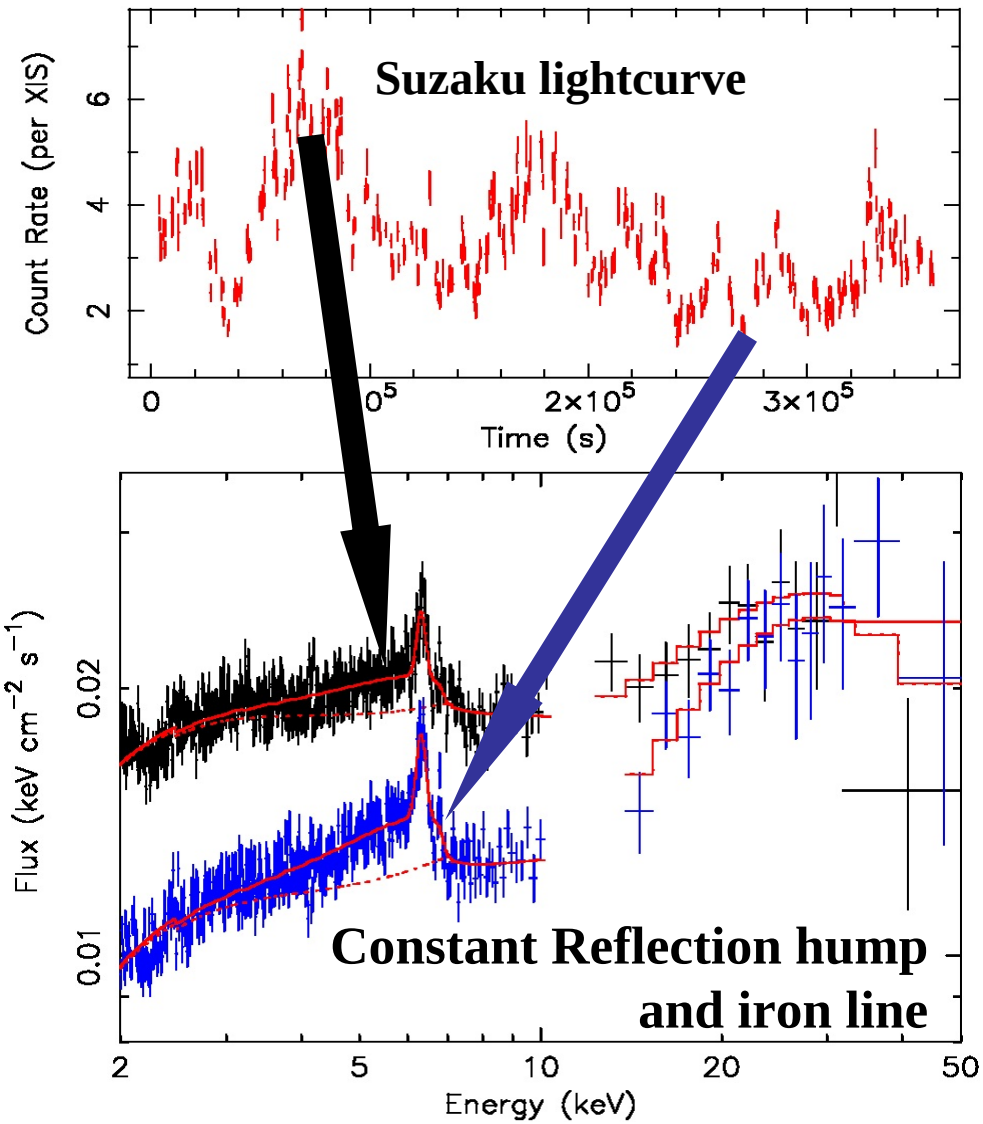


Absorption can explain the spectral curvature below 6 keV - in some cases accounting for part of the broad iron line.

Broad-band Suzaku Observations show the relativistic line/disk reflection in MCG -6-30-15 is robust (Miniutti et al. 2006, PASJ)

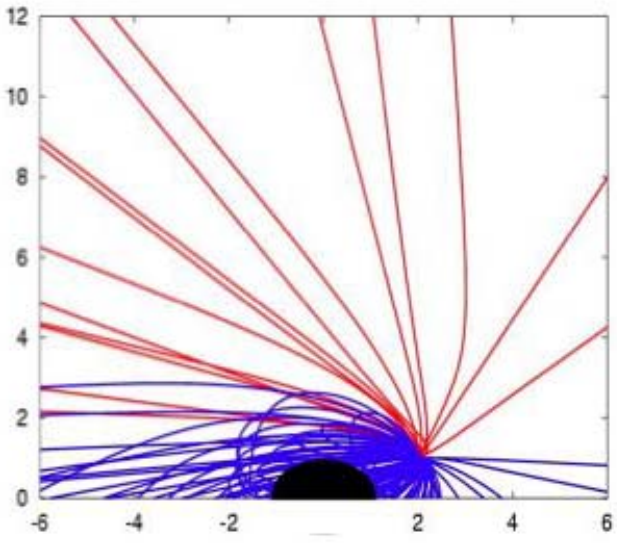


Variability of Iron line and Reflection in MCG-6-30-15

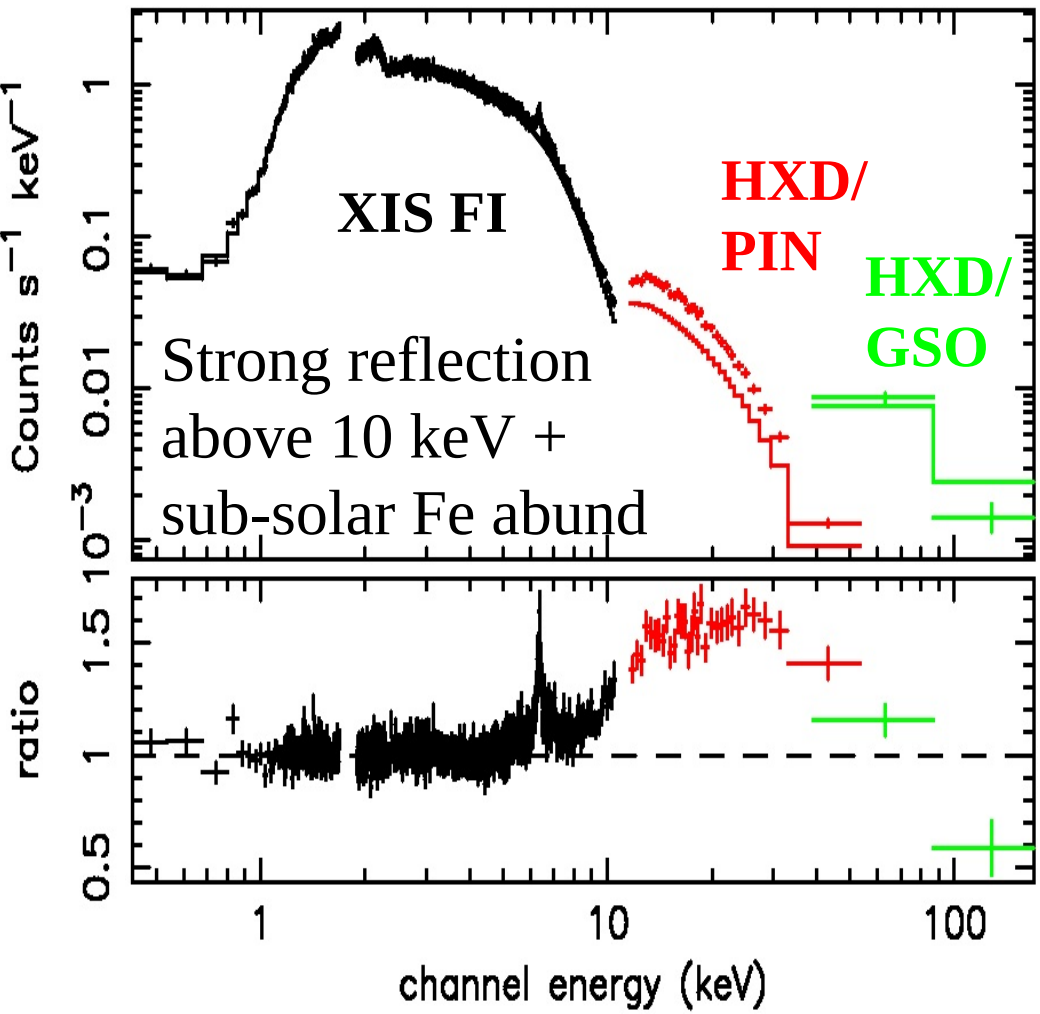


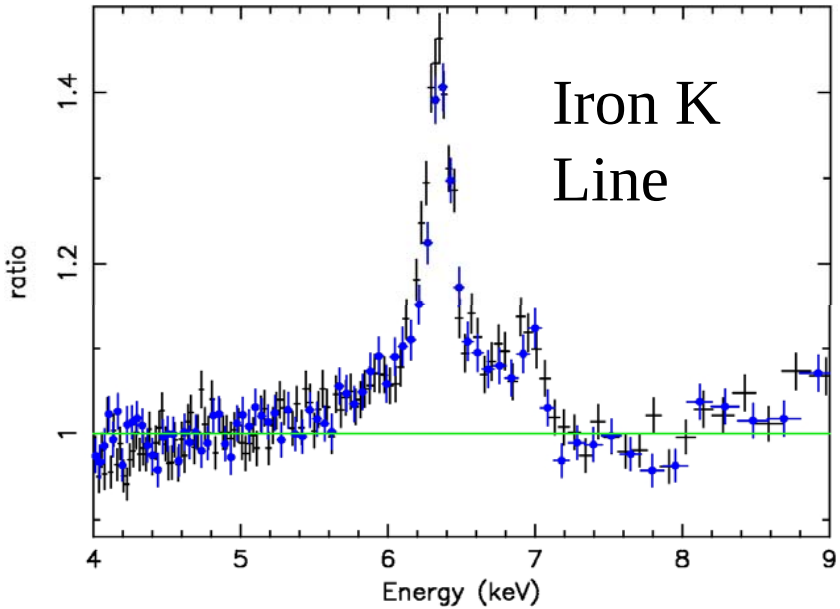
Little variation in Fe line/reflection (few 10s ks timescales) - gravitational light bending around a Kerr BH? (Miniutti & Fabian 2004).

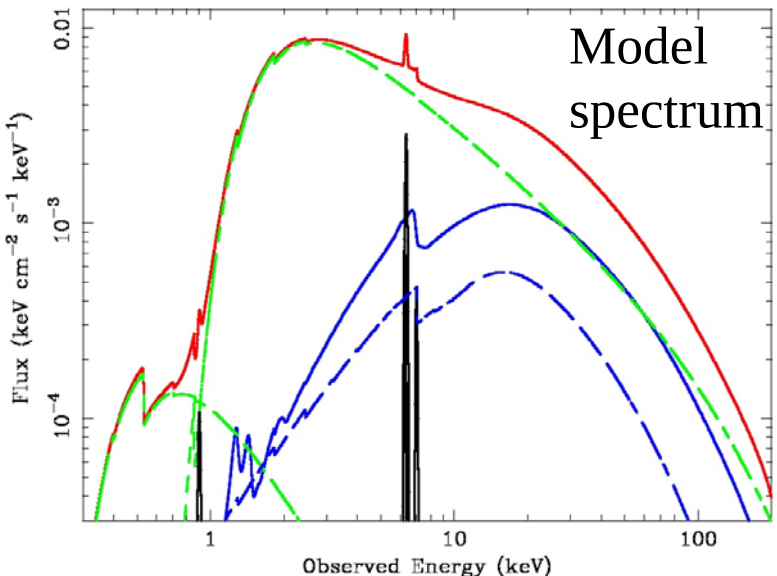
However current instruments cannot probe orbital/dynamical timescales (<few ks) for Fe line/reflection in most AGN



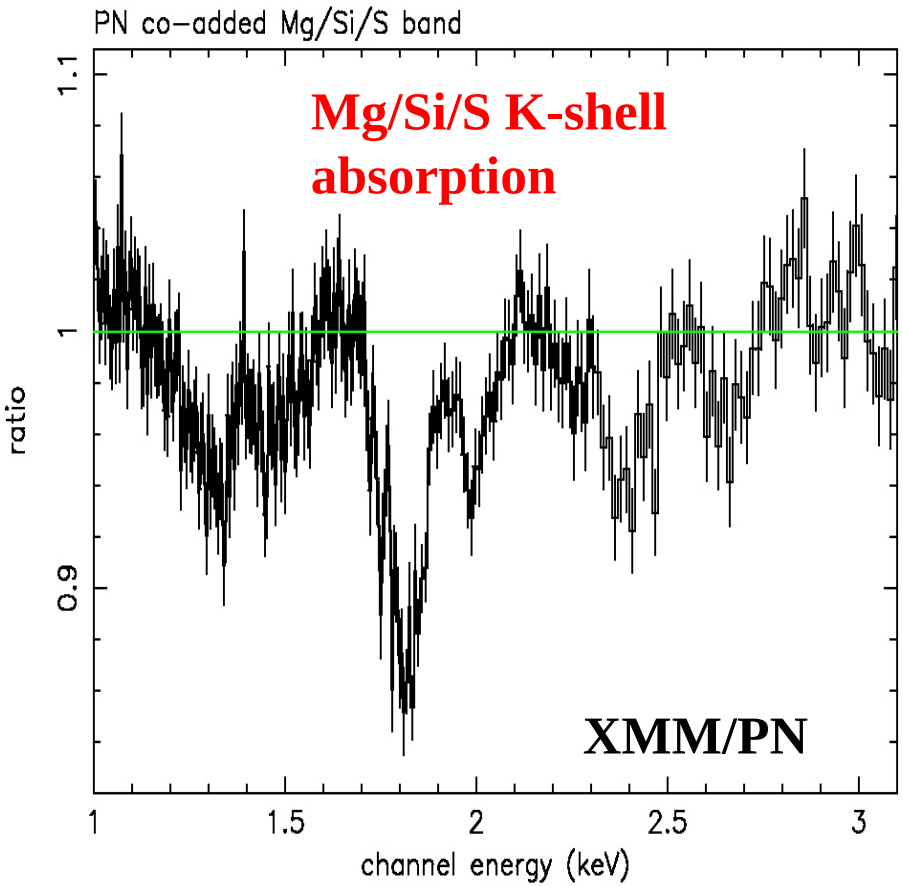
Suzaku Spectrum of MCG -5-23-16 (Compton-thin Seyfert 2, z=0.008486; Reeves et al. 2006, PASJ)

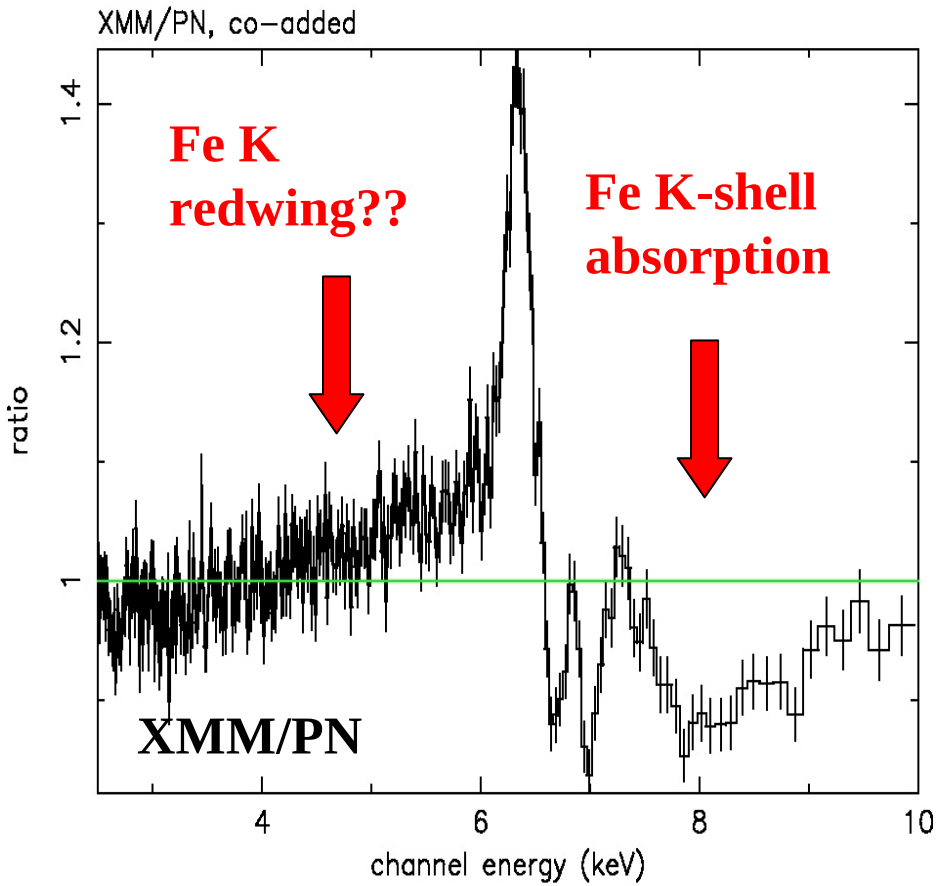






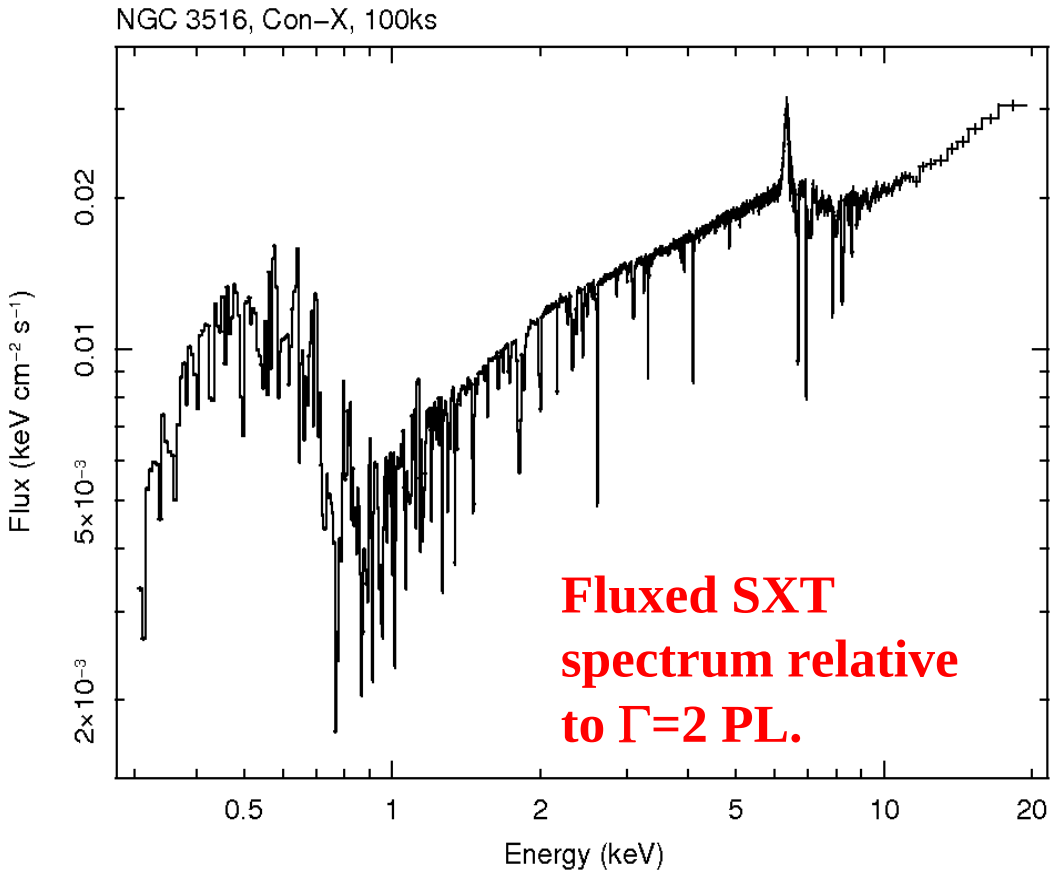
A Case Study with Con-X:- the Seyfert 1 NGC 3516



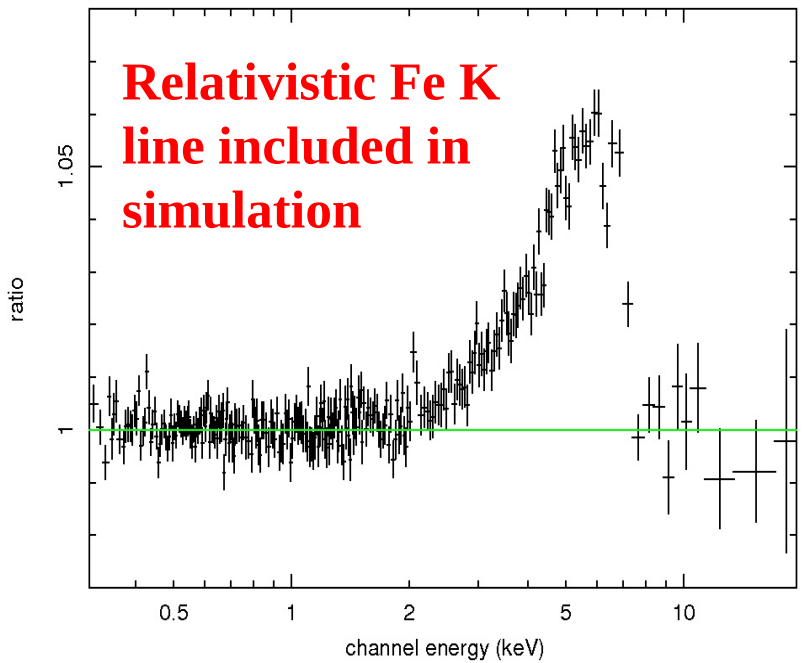


XMM-Newton 200ks observation of NGC 3516 (PI J Turner) in 2006. Multiple high ionization absorption lines present both in Fe K and medium energy band. Complex absorption over limited bandpass (<10 keV) means broad line solution is degenerate.

Con-X Simulations of NGC 3516 - 100ks exposure



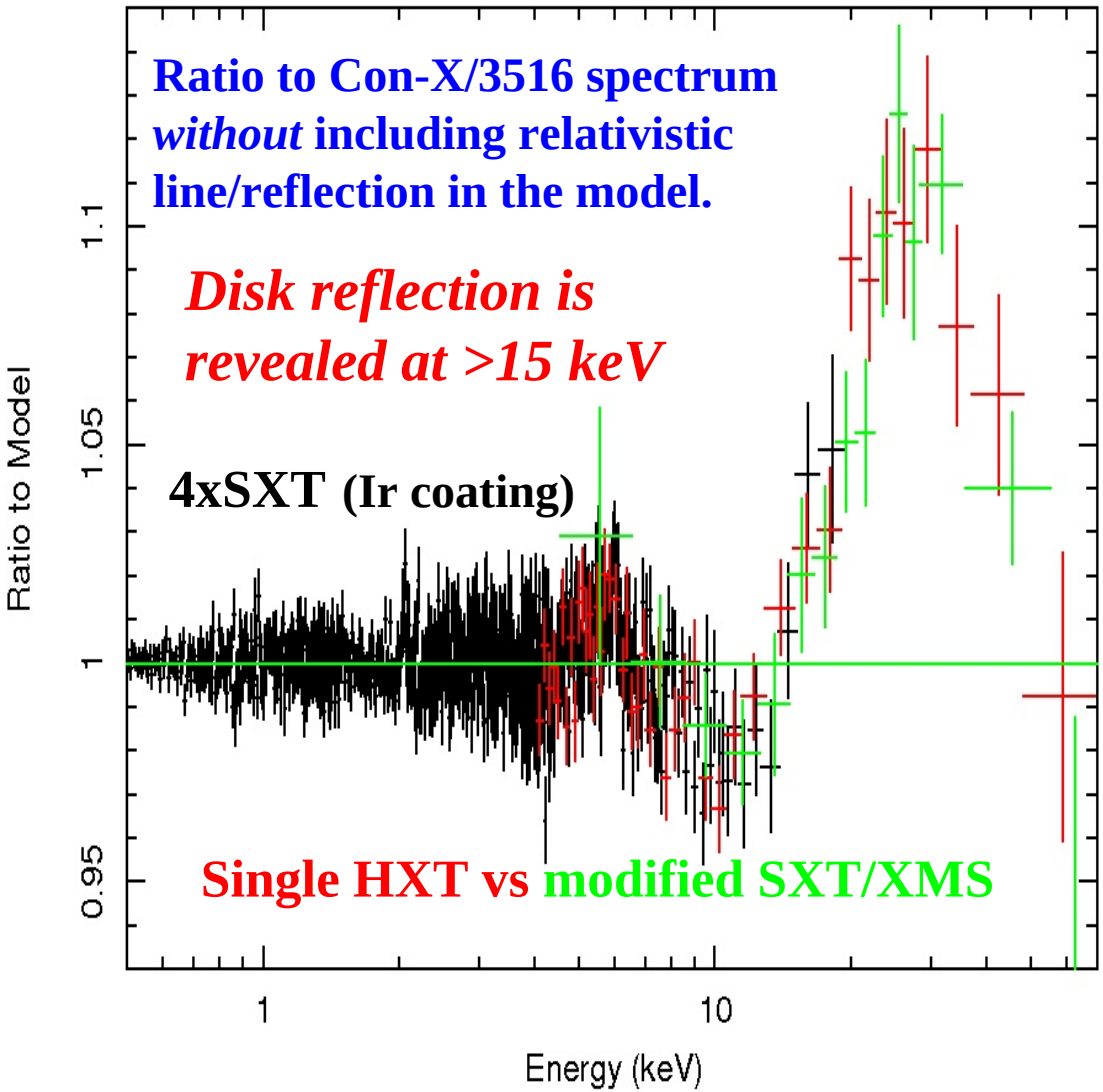
Spectrum includes a relativistic line (200 eV EW) from around a Kerr BH, as well as the smeared disk reflection continuum (the distant reflector is also included).



NGC 3516 Con-X spectrum derived from XMM best-fit model

Model includes complex ionized absorption (4 layers)

Hard X-ray bandpass is crucial for revealing the relativistic disk reflection



Simulated NGC 3516 spectrum refitted without including broad Fe line nor disk reflection component in the spectral model.

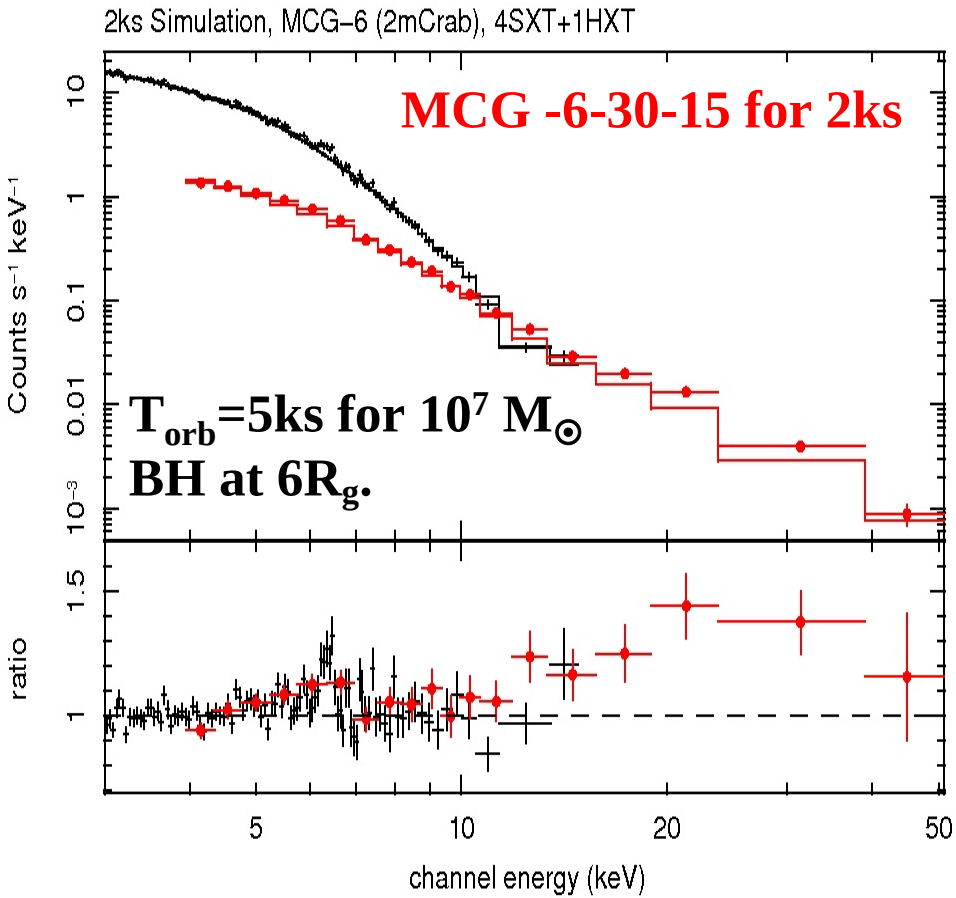
Degeneracy in fit solution between absorber and broad Fe line below 10 keV

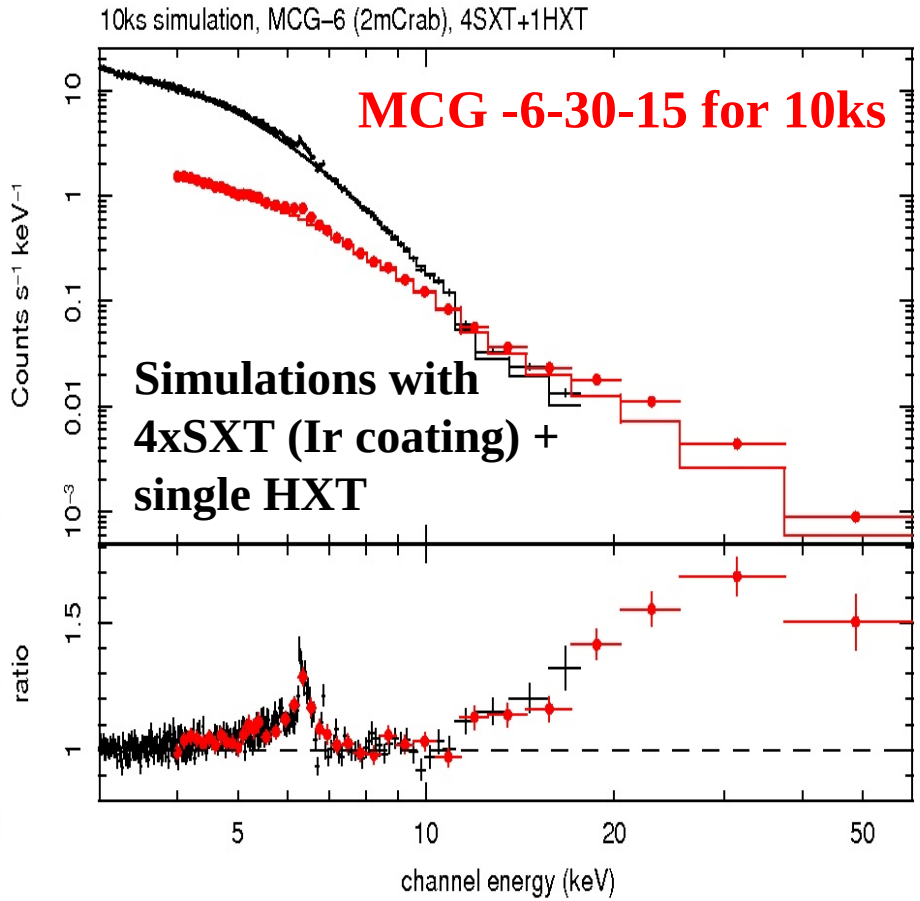
However above 10 keV, the disk reflection component is clearly revealed.

Broad-bandpass (e.g. a proposed HXE) is important for unambiguous modeling of relativistic lines.

~200-300 cm^2 of effective area at 25 keV

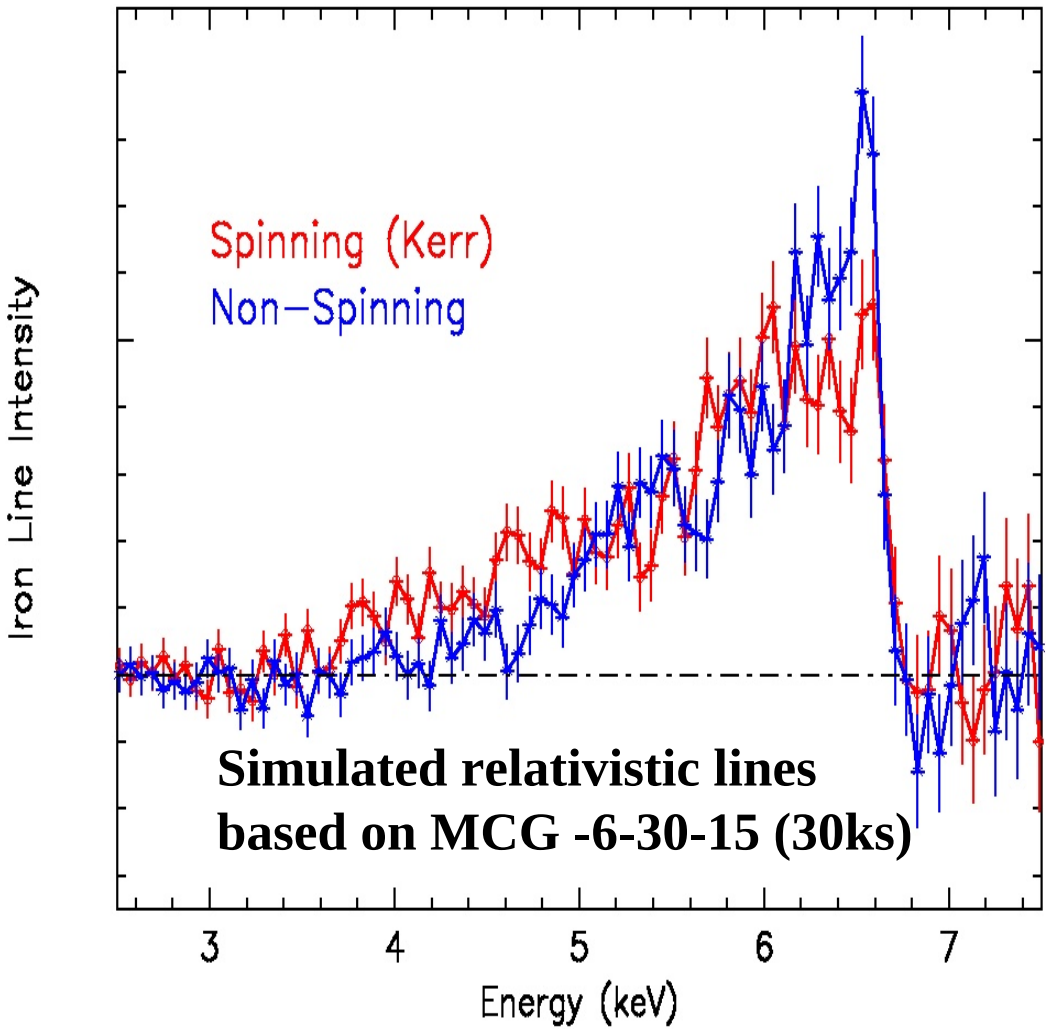
Improving constraints on relativistic Fe K line variability by adding high energy response





Broad line+reflection constraints improved by including a HXE. Even in 2ks, "R" can be constrained to 40% (vs no constraint without HXE) and the iron line parameters to ~30% accuracy (x2 improvement). ***A modest HXE improves the feasibilty of tracking variations in Fe K and reflection on <orbital timescales***.

Measuring Black Hole Spin



With high S/N line profiles the black hole spin can be constrained (e.g. via the IMCO).

Typically 1e6 counts with SXT (2-10 keV) band are required for ~10% accuracy

Including a HXE improves continuum determination - lowering counts threshold for spin (~250000 counts, SXT)

Increases no of AGN for possible spin measurements from ~150 to >500 within a reasonable total observing period (~10 Ms of observations)

Conclusions

- Complex AGN spectra require ***both*** high spectral resolution and broad-band pass to unambiguously model relativistic Fe K lines. Even in complex cases (e.g. NGC 3516), degeneracy between complex absorption, HE reflection and the iron line profile can then be broken.

- Additional high energy bandpass substantially improves constraints on reflection parameters as well as the broad iron line.

- Including a hard X-ray enhancement makes it possible to track iron line profile + reflection changes in bright AGN on the shortest (sub-orbital) timescales. Constraints on spin are also improved in the time-averaged profiles (due to better continuum determination)

- ***Thus in addition to high spectral resolution, broad-bandpass is an important ingredient to make precise measurements of strong gravity around massive black holes.***